Galactic Bulge Observations

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The mid-infrared spectrometer (MIRS) that flew on the joint NASA/Japanese Space Agency Infrared Telescope in Space (IRTS) mission in 1995 yielded a wealth of data that are presently being analyzed and reported on. Here we present the results of MIRS studies of the Galactic Bulge region.

The MIRS operated over wavelengths ranging from 4.6 to 11.7 microns with a spectral resolution of about 0.23 to 0.36 microns. This is an ideal spectral region and resolution for investigations of infrared emissions from solid material, since it covers many of the diagnostic stretching and bending modes of candidate interstellar material. The IRTS/MIRS telescope/instrument combination achieved sensitivities that were orders of magnitude better than those of any other instrumentation previously used for diffuse mid-infrared emission studies.

Analysis of the MIRS results was performed for four locations in the Galactic Bulge region with galactic longitude and latitude coordinates of 8.7°, 2.9°; 8.7°, 4.0°; 8.7°, 4.7°; and 8.7°, 5.7°. The MIRS data were averaged over effective beam sizes of 8 × 20 arcminutes and corrected for interstellar extinction based on results from the Cosmic Background Explorer mission. Analysis of the data from the Infrared Astronomical Satellite (IRAS) mission indicates that the MIRS diffuse emission measurements had at most a 10% contribution from IRAS 12-micron point-sources.

Below galactic latitudes of 4.0° in the Galactic Bulge, the MIRS spectra are very similar to those from M and K giant stars. The unidentified infrared bands at 6.2, 7.7, 8.6, and 11.3 microns were also detected; it is likely they originate from emission from the diffuse interstellar medium in the bulge. Above galactic latitudes of 4.0°, the MIRS spectra are similar to the spectra of evolved stars with the high mass-loss rates seen by IRAS. One likely interpretation is that this emission arises predominantly from a large number of low-luminosity stars that were not detected by IRAS. The age of such low-luminosity stars would have to be at least 12 billion years, and the existence of such a large number of evolved stars with high mass-loss rates in the bulge would have a significant effect on our understanding of the stellar content and evolution of the Galactic Bulge. Furthermore, since the characteristics of the Galactic Bulge region are similar in many ways to those of elliptical galaxies, these results may shed light on the origin of the excess mid-infrared emission that has been observed on some elliptical galaxies.

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Photochemistry of Interstellar and Cometary Ice Analogs

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Ames Research Center has made major contributions to the understanding of the composition and properties of interstellar and cometary ices. This is done, in part, by studying how laboratory ice analogs are modified by various kinds of chemical processing, for example, by ultraviolet (UV) irradiation. These laboratory studies, coupled with telescopic observations, show that the main components of cosmic ices are simple molecules like water (H_2O), methanol (CH_3OH), carbon monoxide (CO), carbon dioxide (CO_2), and ammonia (NH_3). Ultraviolet irradiation of such ices produces "hot" hydrogen (H), carbon (C), oxygen (O), and nitrogen (N) atoms and radicals like formyl radical (HCO) which ultimately combine with other species in the ice to make new, often more complex, organic molecules. Interstellar materials made in this manner may ultimately seed planetary systems that form within dense clouds with molecules crucial to the origin of life.

This paper reports on the chemical processes that occur when polycyclic aromatic hydrocarbons (PAHs) are frozen in H_2O-rich ices and then UV-irradiated. PAHs, large aromatic molecules that consist of fused hexagonal rings of carbon surrounded by peripheral hydrogen atoms (an example is shown in the figure), are known to be abundant and ubiquitous in the gas phase in space where their aromatic structure makes them highly resistant to photodestruction. However, in dense clouds, PAHs are efficiently frozen onto dust grains where they will be exposed to UV radiation. Under these conditions, PAHs will not just be exposed to direct interactions with high-energy photons, but will also experience chemical attack by "hot" atoms and reactive molecular fragments produced when photons strike other molecular components in the interstellar ice.

A large number of experiments were carried out in which various PAHs were frozen in H_2O ices at 12 kelvin and then exposed to varying amounts of UV radiation. After photolysis, the ices were warmed and the remaining room-temperature residues collected. The samples were examined using infrared spectral techniques before, during, and after deposition, irradiation, and warm-up. The room-temperature residues were also examined by the chemistry group of Richard Zare at Stanford University using the technique of laser desorption-mass spectrometry.

The results of the infrared and mass spectrometric studies demonstrate that PAHs frozen in ices are indeed more susceptible to modification by UV irradiation than are PAHs in the gas phase. The alteration of the PAHs appears to occur along several different pathways, represented graphically in the figure, that involve the addition of hydroxyl radicals (OH) groups, O atoms, or H atoms to the peripheral carbon atoms on the PAHs. The result is the production of PAHs containing alcohols, ketones, ethers, and aliphatic hydrocarbons as peripheral functional groups.

These processes add significantly to the molecular complexity of the material and have several important implications. First, oxidized forms of PAHs are thought to represent important cancer risks, and the photolysis of PAHs in ice grains in the upper atmosphere may represent a significant pollution risk. Conversely, PAHs having these kinds of structures are common in primitive meteorites and, as the figure shows, are very similar to compounds critical to the chemistry of living systems. Thus, the photolysis of PAHs in interstellar and cometary ices may have had a part in the production of compounds that played key roles in the origin of life.

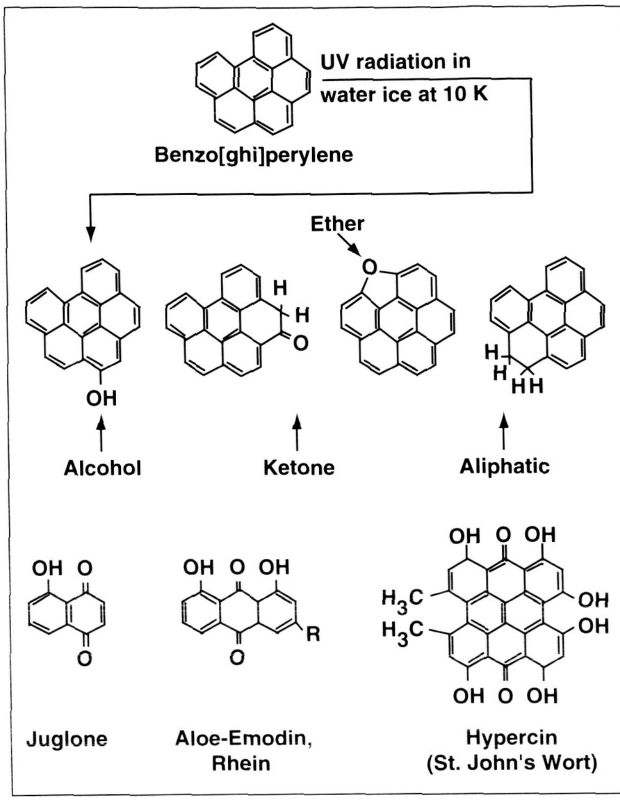

Fig. 1. The molecular structures (top) that are formed when a polycyclic aromatic hydrocarbon (in this case, benzo[ghi]perylene) is UV-irradiated in an H_2O ice at 12 kelvin. The new functional groups produced on the periphery of the molecule include those of alcohols, ketones, ethers, and aliphatics. The structures (bottom) of juglone, aloe extracts, and hypercin, are examples of aromatic molecules that are important in living systems. The peripheral structures of these molecules are very similar to those seen in the upper portion of the figure.

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